Swan & Canning Rivers Bridges

Australian Engineering Week Tour 2012

Presented by Engineering Heritage Panel

INFORMATION BOOKLET

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Contents

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About the Engineering Heritage Panel

Mission Statement

To establish principles and techniques, and to foster ways and means by which the Institutionof Engineers and the general public can access and comprehend Australia's rich engineering heritage.

Objectives

- *To promote the engineering heritage interest of all members of the WA Division of the Institution, the engineering profession and industry.*
- *To promote and participate in the identification and conservation of items of engineering and industrial heritage, including sites, structures, artefacts, photographs and similar.*
- *To encourage research on these items, on the biographies of engineers, on the history of engineering, engineering organisations and industries.*

Causeway Bridges

The Causeway Bridges under construction

Situation prior to the construction of the present bridges

The navigation channel was bridged by a humped structure, situated at the eastern end of the causeway where the present road roundabout is situated. For many years after construction was finished the presence of piles cut off during the demolition of this bridge was revealed by lumps in the road surface as the fill placed in the channel settled.

The present channels replaced two shallow channels through mudflats roughly in the same location. These were deepened with improved alignment to provide for navigation and to accommodate floods. The spoil was used to construct Heirisson Island.

The 1864 bridges were of one lane, probably 12 feet wide. The original deck timbers of those bridges were still there in the widened timber structures at the time of construction of the new bridges. They and the widening were covered with a bituminous concrete of considerable depth in which the rails for the tram were situated on the newer widening on the eastern side. Deck planks were frequently broken.

As a point of interest, treated karri was used for both pier half caps and decking for a number of bridges including Garratt Road Bridge and the Canning River Bridge on Albany Highway. As noted by Lloyd Margetts, in his history of the Canning Bridges, the timbers were eaten from the inside out by the termites entering through bolt holes. They gained access to the piers through the wandoo stringers, most of which are hollow. So the first time anyone was aware of the termite attack was when a half cap was crushed or broken.

The Causeway Bridges

The eastern bridge is 725 feet (221 m) long and the western one 376 feet (115 m) long. The longer bridge consists of eleven 61 feet (18.6 m) spans and a relieving span of 27 feet (8.2 m) at each end. The shorter bridge at the western end has five 62 feet (18.9 m) spans and relieving spans of 33 feet (10 m) at each end. Provision was made for a vehicular way 27 feet (8.2 m) wide (three lanes in each direction) and pedestrian footways 8 feet (2.4 m) wide with accommodation for all services such as water and gas mains under the deck.

Construction of Piers for the Existing Bridges

These were built inside coffer dams consisting of driven timber piles supporting guides through which 75 mm thick karri birdsmouth sheeting planks was driven. The planks were 225mm wide and were 90º pointed on one edge and a 90º slotted on the other. They were pointed with a splayed cut at the bottom to wedge the plank being driven hard against the preceding one by the pressure of the soil being displaced. Walings were needed at frequent intervals during dewatering and excavation of the mud from within the dams as the pressure of the water and mud outside was likely to bend the sheeting below the bottom waling inwards extruding the mud inside upwards.

The pile groups under each line of deck girders were then driven, pile caps cast, a trapezoidal extension cast on top narrowing down to the size of the columns a little below water level. The columns are contained within curtain walls and transverse top and bottom beams. The piles in my recollection were karri, not jarrah. They would be immune to rotting and borer attack being encased in fully saturated mud.
The abutments for the relieving spans at each end of each bridge were founded on reinforced concrete piles rather than timber piles as a considerable length of pile was above permanent ground water level and would be subject to rot attack. The relieving span piles were encased in embankment fill which was over a considerable depth of highly compressible

soft clay. This created a problem at the western relieving span abutment of the western bridge for two contributing reasons. Firstly negative friction on the piles would have loaded the piles to such an extent that they were driven further into the founding stiff clay below and, secondly, the embankment load would have led to consolidation of the foundation clays below the toe level of the concrete piles exacerbated by a greater depth of relatively soft foundation clay below as the piles reached their design penetration per hammer blow well above the level of the timber piles of the adjacent bridge abutment piers. No doubt the bridge abutment piers would have settled a little due to the effect of the nearby embankment, but it would have been millimetres compared with centimetres of the relieving span abutment.

A further problem may have been created by the use of rapid hardening cement for the relieving span piles of one of the relieving span bridges due to lack of normal cement at the time. Rapid hardening cement is low in alkali, which normally passivates the steel, so delaying corrosion after penetration of water. As the river water is salty for much of the year the problem is exacerbated. To my knowledge no problem due to corrosion of the steel in these piles has yet become apparent.

Construction Plant

Timber pile driving frames, with steel channel faced pile driving hammer guides, were used. These were often built for each job, the pile driving gangs becoming so skilful they could knock one up very rapidly without any plans. The hammers consisted of a trapezoidal shaped lump of cast iron with a tongue down the back to fit between the guides and generally weighed 2 tonnes for timber plies and up to 6 tonnes for concrete piles. Double drum winches were located in a convenient place to lift and drop the hammer. The coffer dams provided in the case of the Causeway bridges were used to support the gear for driving the foundation piles inside the coffer dams, the coffer dam support piles having been driven from a barge mounted pile driving rig.

Mobile cranes, except for small capacity fixed (non traversing) truck mounted cranes, were unavailable at the time, though we had the services of a steam driven floating crane from the Harbours and Rivers Department. This was used to place the bridge girders but didn't have the reach to place concrete on the deck. There was no such thing as ready mixed concrete, so the mixing plant was situated on an approach embankment to each bridge so the concrete could be delivered on the level or downhill in hand pushed bottom dump skips mounted on narrow gauge rail trolleys.

Concrete Mix Design

Main Roads Chief Bridge Engineer Ernie Godfrey knew how to make good concrete. His bible was the US Bureau of Reclamation Handbook. The Bureau was very clued up on concrete durability. The aggregate cement ratio of the concrete used in the Causeway Bridges was 4.5 and the water cement ratio if I recall correctly was 0.4.

As cement was in short supply, supplies were double ordered from all over the world to try and ensure timely deliveries. We had cement from England, Sweden, Japan, South Africa and the Eastern States as well as local Swan Cement. The cement from UK, Sweden and Japan had a high alkali content and we found later that it reacted expansively with the aggregate available from the local quarries. This aggregate was epidiorite quarried from seams within the granite of the Darling Scarp. Most of the aggregate production at the time was produced for road surfacing and granite or grano-diorite was not then used as they are acid rocks to which bitumen won't stick without an additive which I guess was not then available or it was cheaper to use the basic igneous rock. The trouble with the epidiorite was that it was extremely fine grained due to it having cooled rapidly as it was intruded in thin seams into the pre existing granite. It appeared that \the large surface area of these grains allowed the cement to attack it. This was a bit of a surprise as crystalline rock was supposed to be immune to cement-aggregate reaction. We had done no testing as a consequence, which we always did if the presence of amorphous silica was suspected.

There was no record of any trouble with the local cement which had a lower alkali content. In any case the pier surfaces below high water level had been painted with a thick bitumastic coating to retard water penetration. The underside of the bridge deck was also painted with this coating to prevent penetration of water condensation.

The Causeway Bridges under construction

The Composite Deck

Steel beam/concrete deck composite construction was first used in Tasmania where Alan Knight introduced it in the 1930s. Knight was the Chief Engineer of the Public Works Department of Tasmania. I believe Knight was the first in the world to use the technique. It was subsequently widely used in the USA and also notably in Germany on the reconstruction of many large bridges destroyed during the second World War. In the USA the technique was further developed by the use of steel studs in place of the reinforcing hooks initially used to bind the bridge deck to the steel beams.

As far as I am aware, the Causeway bridges were different from any of the Eastern States composite bridges in that the

concrete slab was prestressed by securing the ends of the simply supported steel girders and jacking up in the centre (at the third points), casting the concrete and when cured lowering the jacks, transferring longitudinal compression into the concrete. Jacking trusses spanning between piers beneath the girders supported the jacks. This overcame the tendency which had occurred in many of the Eastern States bridges for shrinkage cracking to develop into more serious cracking under the effect of heavy traffic.

Such prestressing was widely used in Germany to control cracking which would otherwise allow the intrusion of salt laden water from de-icing salt with serious corrosion consequences, particularly in the negative moment regions of continuous bridge decks. Most of the bridges there were of continuous construction to avoid deck joints which often present maintenance problems. This prestress involved jacking up the whole length of the bridge girders in huge arcs before concreting. In long bridges jacking heights were as much as 4 m or more.

We in WA developed a span by span technique for continuous bridges, by jacking and casting from ¾ point to ¾ point of the next span which only involved raising and lowering the girders at the piers on small hydraulic jacks by 75 mm in 18 m, regardless of the length of the bridge. The prestress varies along each span but is heaviest where it is most wanted in the negative moment region. A number of bridges were built using this technique in the Pilbara and it was very economical. Heavy shrinkage reinforcing though, can be used to control cracking in bridge decks. Normal shrinkage reinforcing is inadequate in this situation as shown in one of the bridges in the Pilbara and in several bridges in Victoria that were not prestressed.

Construction Time

The long construction time of the existing bridges (1947 - 1952) was dictated to a large extent by the shortage of the materials required. The bridges were constructed by the Main Roads bridge construction crews with about 50 men being employed.

Official Opening

The bridges were officially opened on 19 September 1952 by the then Premier of Western Australia, The Hon Sir Ross McLarty, MLA, assisted by his Minister for Works, The Hon David Brand, MLA. Mr J D Leach was the commissioner of Main Roads and Mr E. W. C. Godfrey the Design and Construction Engineer. At a time of financial austerity prevailing when the bridges were built it was a tribute to the skill of Main Roads bridge engineer Ernie Godfrey that innovative bridges could be constructed economically in the state. It was the first bridge in the Western Australia to utilise composite steel/concrete construction, shortly after its pioneering use in Tasmania.

Prepared by Gilbert Marsh supplemented with material provided by Lloyd Margetts

The completed Western Bridge

Narrows Bridge (1959)

The Narrows Bridge under construction showing N&S Double Cantilever Beams completed

History of the Narrows Bridge

As early as September 1849 articles appeared in the Perth local press as to the desirability of constructing a bridge at the Narrows site to improve the communications between Perth and Fremantle in lieu of the "tedious and protracted route via the Causeway bridges" which were built in 1843.

A proposal for a bridge of eleven spans was mooted in 1899. The estimated cost of 13,000 pounds was greeted with dismay. The Public Works Department next in 1901 prepared a sketch plan for a timber bridge 900 feet (274m) long with central swing spans but that scheme also did not proceed.

Preliminary reports and sketch plans for a bridge at the site were prepared by the Main Roads Department in the period 1947-1953 but action was postponed because the Departments's resources were fully committed to the building of the Causeway bridges. Surveys conducted in 1954 revealed that traffic over the Causeway had more than doubled in the preceding five years and as a consequence the MRD proposed to the Government that a bridge should be built across the Narrows.

In August 1954 the Labor Government of the day decided that a bridge should be built as soon as possible. Works Minister John Tonkin announced that foundation test work would commence immediately and the estimated cost of the bridge based on MRD tentative plans would be 1,750,000 pounds.

The Government decision was welcomed by Town Planner Gordon Stephenson who forecast a northern approach road to the west of the City of Perth and extensive parking facilities on the reclaimed area of land between the Narrows and the Esplanade.

Due to the difficult foundation conditions revealed and the consensus that the bridge design should provide for slender spans the MRD Chief Engineer E. W. Godfrey was sent overseas in May 1955 to consult with bridge engineering authorities. In September of that year Maunsell, Posford and Pavry of London were appointed design consultants and commissioned to prepare detailed plans for the construction of the bridge.

A design for a prestressed concrete bridge comprising a slender, elegant structure of five spans was subsequently submitted by the Consultants and approved by the Cabinet in April 1956.

The Narrows site prior to construction circa 1956

Bridge Statistics

The overall length is 1100 feet (335m) ; comprising a centre span of 320 feet (98m) and flanking spans of 230 feet (70m) and 160 feet (49m).

The superstructure consists of 8 rows of I beams each continuous over their full length. The beams vary in depth from 4 feet 11 inches (1.5m) at the abutments to 13 feet 9 inches (4.2m) at the river piers. The webs of the I beams have a thickness of 8 inches (200mm). The beams are fixed at the north abutment and a Demag expansion joint at the south abutment caters for movements of plus or minus 3.5 inches (90 mm) due to temperature, shrinkage and creep.
The overall width of the bridge deck was 90 feet (27.4m) made up of roadway 70 feet (27.4m), footways 8 feet (2.4m), safety fences erected 2 feet (0.6m) from kerbs. The clearance under the central span is 26 feet (8m) above normal water level, road clearance 15 feet (4.5m) for the land spans.
The gradient of the bridge deck comprises a profile of a vertical curve joining tangent lines of a grade of 1:25 on the approach embankment.
The balustrading and safety fences are of anodized aluminium and the lighting comprises aluminium standards at 80 feet (24m) centres with three 80 watt fluorescent lanterns.
Services consist of five 30 inch (726mm) water mains, a 30 inch (726mm) sewer main, two 15 inch (381mm) gas mains and telephone and power cables.

Approximate Quantities

Gambia Piles: 180 Nos., 20960 lineal feet (6390m)
Portland cement concrete : 12,600 cubic yards (9600cm)
Mild steel reinforcing : 1900 tons
Prestressing strand : 325 tons
Roadway surfacing : 18,600 square yards (1728 sm)

Design and Construction

Detailed plans and specifications were prepared by G Maunsell and Partners and their associates, architects Sir William Holford and Partners and prestressing consultant, E W Gifford. The design provided for post tensioned double cantilever beams (made up of precast units) supported on the shore and river piers with shore and central suspended spans. The beams were made continuous after the suspended spans were lowered into position.

Three tenders were received and the lowest, for 1,325,000 pounds, from Christiani & Nielsen A/S of Copenhagen, in association with J O Clough and Son, Perth, was accepted on 12 March, 1957. The successful tenderers proposed to erect the precast units making up the bridge beams in their final position, on trestles supported on a piled staging, prior to post tensioning. This was in lieu of the construction method proposed by the Consultants, which involved assembly in the precast yard and the transfer of the completed beams to their final position using a floating crane which would have had to have a capacity of over 500 tons.

The foundations incorporated Gambia piles, so named because of a previous use in the African location of the same name by the Consultants. They consisted of tubular steel piles 31.75

Narrows Staging Piles and Gambia Pile frame

inch (806 mm) OD and 0.375 inch (9.5 mm) wall thickness. The lower section had a conical point which was filled with reinforced concrete in the preparation yard. The piles were driven with 10 and 12 ton drop hammers striking on a steel anvil embedded in the concrete fill. As pile penetrated the sub strata to depths of 110 to 120 feet (33 m to 36m) extension casings were added by welding. Completed piles were subsequently filled with reinforced concrete. Four piles were load tested to twice their working load of 200 tons.

The staging consisted of a grid of some 1500 timber piles, up to 80 feet (24m) long, linked with timber bracing. As well as supporting the precast beam units the staging carried the steel rails on which travelled two pile frames, material transporters, an electric powered gantry crane and a monorail concrete support system A 40 foot (12m) navigation gap allowed for the intermittent passage of marine craft when temporary steel bridging beams were lowered onto the river bed.

Early in 1958 the tops of the staging piles near the north bank were observed to be moving laterally out into the river, although they were unloaded at the time. Investigations revealed that the consolidation of the reclaimed Mounts Bay area had caused a wedge shaped layer of mud to displace laterally thus affecting the staging piles. As a result the Consultants modified the north shore pier Gambia piles by increasing the casing diameter from 31.75 inches (806 mm) to 43 inches (1092 mm) .The insitu concrete column was replaced by an octagonal shaped precast reinforced concrete column, the lower 5 foot (1.5 m) section of which was grouted into the base of the driven pile, allowing the upper part of the casing to move without affecting the position of the pier support column, and hence, the pier itself.

Precast beam units, weighing up to 20 tons, were manufactured in a yard located on the south shore. They were cast in plywood forms made on site. The precast yard was equipped with a pan concrete mixer capable of producing high strength concrete, an overhead monorail system for concrete distribution and an electric gantry for lifting, stacking and loading units on rail bogies for transport to the bridge site.

The abutments, river and shore piers were of reinforced concrete construction cast in purpose made plywood forms. Most of the concrete was mixed on site but some of the large

Narrows Staging, Pile Frame, S Shore Span, Precast yard

abutment pours used pre mixed concrete delivered to the site in agitator trucks. All mild steel reinforcement steel was cut and bent on site.

Superstructure beams were post tensioned after the 9 feet 9 inch (2.97m) long I beams were accurately placed on trestles, the 3 inch (75mm) gaps filled with fine aggregate concrete and the longitudinal stressing cables threaded through the anchor blocks and diaphragms. The Gifford Udall stressing system, employing 19 wire 0.69 inch (17.5mm) diameter strands, placed externally to the webs, was used. Due to the need to access anchorages at the ends of the completed beams the suspended beams had to be post tensioned at an elevated position and jacked down to their final location. The prestressing cables were covered by a pumped grout after stressing and the surface of the grout coated with neoprene.

The external beams are clad with exposed aggregate facing panels made from white cement, white sand and white quartz aggregate, matching the grit blasted soffits of the cantilever footways which were also cast in white concrete.

The bridge was completed in September 1959 and officially opened by the Governor, Sir Charles Gairdner on 13 November 1959.

There is no doubt that the designers and the contractors produced a structure of considerable elegance and world wide repute and amply fulfilled the brief that the bridge should harmonise with the aesthetics of such an attractive site.

The Narrows Bridge was a crucial element in and the first manifestation of the implementation of the 1955 Stephenson-Hepburn Report "Plan for the Metropolitan Region, Perth and Fremantle" which changed the development of metropolitan Perth from a east-west axis to a north-south axis.

At the time of its opening the Narrows Bridge had a number of firsts :

- It was the largest precast, prestressed continuous beam bridge in the world.
- Its centre span of 320 feet (98m) was the longest of its type in the world.
- It was the first bridge in Australia to use a segmental construction method.
- It was the first bridge in Australia to use external prestressing cables, allowing for a minimum web thickness.
- It was the first major public infrastructure project since the end of World War 2 to be constructed by contract.

In 1999 it received Engineers Australia's highest accolade, a National Engineering Landmark Award.

Prepared by Don Young

Canning Bridges

Early Roads and Bridge Planning

It is interesting to note the comments of historians and others that the siting of Perth on the northern banks of the Swan River was a decision effectively taken in haste by Captain James Stirling during a reconnaissance visit to the Swan River area in March 1827. He decided that the location at the foot of Mount Eliza was preferable for the townsite because he considered it had better access to building materials, streams of water, and facility of communication. It is quite significant that the two other Swan River settlements – Fremantle and Guildford, were both south of the river, as was all of the early farming development and also the earlier King Sound settlement. It would not have been unreasonable for the capital to have been proclaimed south of the river, on the South Perth Peninsular. Since that time, and only really redressed by the planning initiatives of the Stephenson-Hepburn plan and its successors, the economic and commercial development of Perth has been skewed towards the northern side of the Swan River.

So at the start, the river was the first real highway, with small boats and lighters plying between the ocean port of Fremantle and the inland ports of Perth and Guildford. Land cultivation was focussed along the river banks, and the combination of sandy soil and lack of community capital meant that a reliable road system would be a long way off.

During his stay at Cape Town while en route to Swan River in 1829 with the first settlers on the "Parmelia" and "Sulphur", Stirling met and recruited an unemployed engineer/architect, Henry Reveley. On the voyage across the Indian Ocean, he was formally appointed the colony's Civil Engineer by Stirling acting under his authority as Lt Governor. Reveley remained in this office until his resignation in 1838, when he departed the colony. He proved himself to be versatile and competent in both the architectural and engineering fields.

Early town allotment and building regulations were promulgated by Stirling and he appointed Land Commissioners for road and bridge construction, and "to assess on each house its proportion of the expense". The first Land Commissioners were the Government officials, John Septimus Roe (Surveyor General) and George Fletcher Moore (Advocate General).

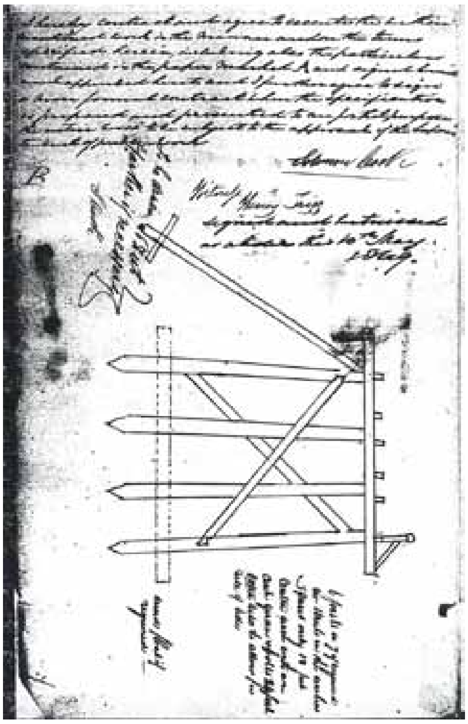
Very little was achieved by the Commissioners, and the state of the roads was a constant source of grievance to the early settlers. For many years town streets comprised ankle-deep sand, were a dust nuisance, and were without footpaths. In 1837 Stirling reported to the Secretary of State for Colonies that:

"At the present time it can scarcely be said that any roads exist, although certain lines of communication have been improved by clearing them of timber and by bridging streams and by establishing ferries in the broader parts of the Swan River ..."

It should be noted that only one substantial bridge was built in the Swan River colony during the first fourteen years of settlement, and that was the 1835 construction of a timber bridge at Drummond's Crossing, across the Helena River at Guildford. When the water levels are low, you can still find remnants of this bridge behind the polo ground at Guildford on the old alignment of Drummond Street.

In 1838 new legislation was passed which replaced the Land Commissioners. It provided for the establishment of Town Trusts to manage roads, bridges and ferries within town sites; and outside of towns for roads, bridges and ferry management to be vested in a General Road Trust. However, George Fletcher Moore's comment at the time was that "everybody wishes to have roads made, but nobody wishes to pay for them."

Following Reveley's resignation, Stirling downgraded the office of Civil Engineer to that of Superintendent of Public Works. He appointed Henry Trigg, a local builder, to this position.



Extract from Specification for 1849 construction contract.

The First Canning Bridge

The first Canning Bridge was designed by Henry Trigg in his position as Superintendent of Public Works. Tenders for this structure were first called in the "Perth Gazette" of December 26, 1846 but the prices were considered too high. Tenders were re-called in 1849 and a contract was awarded to Solomon Cook. He completed the bridge in 4 months at a cost of 425 pounds. The bridge was 520 feet long and 12 feet wide, with a deck 8 feet above high water. With river navigation such a feature of colonial life at the time, the central span was extended to 24 feet to allow boats to pass underneath. The construction of the bridge was widely reported as quite rough, and Henry Trigg had claims against the contractor for the way many of the piles were driven, but the bridge was still a welcome improvement for the settlers who no longer had to use the slow and expensive ferry crossing.

It is worth just noting the achievements of Solomon Cook – he seems to be one of those people who could turn his hand to any technical matter, and had a hand in running mills as well as building and maintaining bridges over a period of years. Among other achievements he built steam-powered

boats which were used on the Swan River in the 1850's and he established a foundry in Perth on the site later occupied by Boans/Myers.

The 1862 Flood

The Swan and Canning Rivers have a long history of flooding, although river training, dredging and dams have lessened the effect in recent years. Many people will recall the inundation of Guildford and South Perth in 1955, and as recently as 1926 flooding has caused the collapse of bridges at Fremantle and Upper Swan. Prior to this, however, the great flood of 1862 was one of the most widespread and severe floods in the State's recorded history.

Records of the day reported flooding along the Swan River from Guildford, the Maylands Peninsular, across the Perth and South Perth Foreshores, and into the streets of Fremantle. There was widespread damage to roads and bridges, with major bridges being washed away at Northam and Pinjarra and others severely damaged on the Canning, Helena, Moore and elsewhere.

The "Perth Gazette" records that "for some days the Causeway at the Perth Flats was entirely under water and for a time nothing was visible there but the centre portion of the flanking of the first bridge". At the peak of the flood, the Causeway had between 7 and 8 feet of water flowing over it. The Canning Bridge was another of the bridges badly damaged by the flood.

Canning Bridge – 1867

Canning Bridge, in 1867 after reconstruction,

Following the damage of the 1862 flood, a second Canning Bridge was built by convict labour in 1867. From descriptions, the position of this bridge must have been very close to the present upstream bridge.

The new bridge had 26 foot and 27'6" navigation spans, with the 38 remaining spans being 13'6" each – a total length of 572 feet long and 11'2" trafficway width.

This bridge was raised by 6 feet to give increased navigational clearance, to 18 feet above normal water level, in 1892. There is a story about a large dredge being caught upstream of the bridge on the Canning River during this period, but I have found it hard to reconcile the story as written. It would seem to me that the dredge may well have been taken upstream through the bridge in 1892 when the superstructure had been removed for the raising, and then the extent of any miscalculation would have become apparent 4 years later when they had completed the upstream Canning River dredging works and were trying to move the dredge back through the Canning Bridge.

There is an interesting quote regarding this bridge from a talk given by Civil Engineer J E G Turnbull in 1911 to the Western Australian Institution of Engineers. "On the old bridge over the Lower Canning ....the roadway was too narrow for vehicles to pass one another. From each end up towards the centre there was a grade of about 1 in 10, so that it was not possible to see from one end to the other. To make matters worse, the approaches curved away in opposite directions at either end. The consequence was that it was quite possible for two drivers to come on to the bridge from opposite ends and not be aware of one another's proximity until they almost met at the top. I have seen this happen more than once, together with the foregone conclusion, which was that after argument, and language, one driver had to back his horse the whole way down the steep grade and off the bridge – a very awkward and possibly dangerous proceeding."

Lack of regular maintenance funding, possibly resulting from the relatively low priority of the Perth-Fremantle road compared to other transport routes, meant that the bridge deteriorated steadily during the 1890's and into the start of the 20th century. I have encountered a report that the bridge was also badly damaged by fire early last century, so its replacement was now becoming critical and State government funding was finally provided in 1907/08.

Canning Bridge – 1908

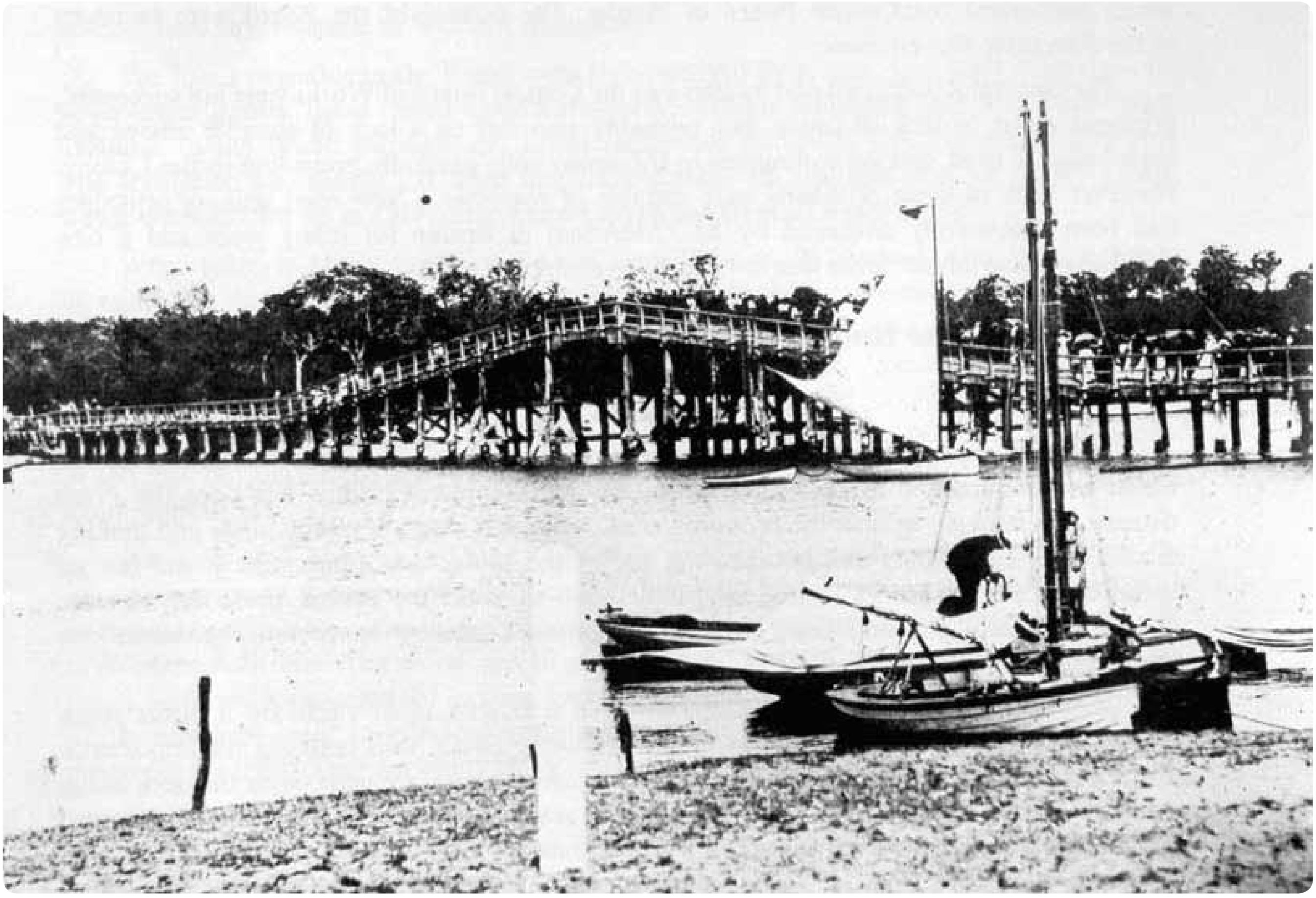
This bridge was sited on an angle south-east of the present bridges, and was known as Lower Canning Bridge, on the Perth-Fremantle Road. The arch over the navigation opening was flattened considerably, down to 1 in 25, compared to the previous bridge. The width of the new bridge was also adequate to allow the traffic of the day to pass each other safely without the dramas encountered by Engineer Turnbull.

It was 570 feet long, comprising 24/20 foot spans, one 40 foot.truss navigation span and 2 short 5 foot support spans bordering the navigational channel. It was 16 feet wide and much stronger than the bridge that it replaced. Built by contract, it cost 2023 pounds.

Starting a tradition which continues to the present day, a fishing platform was added under the bridge soon after it was constructed.

Canning Bridge (No.913) – 1938

The construction of the new Canning Bridge was commenced by Main Roads in July 1937. It was a driven pile timber structure 520 feet long consisting of 24/20 ft spans and a central navigation span of 40 feet, with masonry abutments. The vehicular width was 27 feet, with a 5 foot footway



Canning Bridge, in 1902 after raising

provided for pedestrians. The bridge was completed and officially opened on 29th April 1938 by the then Minister for Works (the Hon. H Millington MLA). The cost of the bridge and approaches was 24,830 pounds.
It is worth noting that this bridge was one of a series of major metropolitan bridges which the WA Government of the late 1930's had directed to have important structural elements constructed from karri timber, to demonstrate its strength and durability – and so the halfcaps were formed from sawn 14"x6" karri, treated with a method known as 'fluarizing'. 'Fluarizing' involves boiling the timber in a mixture of sodium fluoride and arsenic trioxide, producing an envelope of timber which is resistant to rot and termite attack.

After 38 years of service, the bridge deck received a reinforced concrete overlay in 1976.

In 1994/95, the original karri halfcaps had deteriorated to such an extent under the ravages of termite attack that they were replaced with steel. The outside of the timber had been protected by the fluarizing treatment, but termite attack and decay had commenced at bolt holes and similar weak points, and we were left with just a shell of timber holding up the bridge superstructure.

The bridge received a substantial superstructure maintenance and replacement of the reinforced concrete overlay in 1998/99, leaving it in place for many more years of service.

Stephenson-Hepburn Plan 1955

An event of great importance to Perth occurred in Liverpool, England in June 1952 when a group of WA authorities including State Director of Works Russell Dumas first spoke to Professor Gordon Stephenson. The WA Town Planning Commissioner D I Davidson had died, and they were looking to recruit both a new town planning commissioner and a senior consultant in order to develop a comprehensive regional plan for Perth to guide its post-war development. Stephenson arrived in Perth in January 1953 to perform the consultancy role, followed soon after by the new Town Planning Commissioner Alastair Hepburn. They were to form an outstanding and effective team – the academic and progressive Stephenson, who had already had tremendous success in his planning roles at Toronto and at the Greater City of London, and the wise, calm and cautious public servant Hepburn – backed by an enthusiastic and progressive State Government.

In 1955 Stephenson and Hepburn released their "Plan for the Metropolitan Region, Perth and Fremantle, 1955" which discussed in detail many facets of life in the Perth area and suggested how it might be developed for a metropolitan population likely to reach 1.4 million people by the Year 2000. In regional planning, one of the first essentials is to define and establish lines of communication, and so the Plan proposed an extended freeway system to complement and supplement the public transport system. In his 1992 autobiography, Stephenson reiterated his belief that 'a rapid transit system

is not an answer in itself, contrary to the fashionable belief that freeways are bad and a public transport system is good.' He seemed to have a clear grasp of the practicalities of developing a total transport system in a city with the existing development, topography and potential of Perth.

A major effect of the Plan was to change the traditional alignment of the metropolitan region from west to east along the Swan River to north and south. As a result the Swan River, which had been the major factor in Perth's geography and development for over 100 years, became a barrier to further growth. The task for Main Roads would be to provide the major roads agreed from the Plan and to build the bridges for them. The most important road was a freeway running north-south to link the existing major centres of population with the growth areas which would develop north and south of the city. This freeway would be the backbone on which the remodelled Perth was built.

The first part of this spine was the Kwinana Freeway, running from Perth, via a new bridge over the Narrows, along the South Perth foreshore of the Swan River, and linking up with Canning Highway at Canning Bridge.

Canning Bridge (No.912) – 1958 (upstream bridge)

The concentration of traffic on Canning Highway, with allowance for future development meant that Canning Highway needed to be upgraded to a dual carriageway and the Canning Bridge needed to be duplicated. It is interesting to note that the alignment of the new freeway meant that it was desirable to have the new bridge 3 spans shorter than before, to accommodate the new freeway on-ramps. Fortunately, the construction of Canning Dam had reduced the flood flows in the Canning River and not only made the shorter new bridge possible - the existing bridge was also shortened by 3 spans at the eastern end, resulting in matching 22-span 2-lane timber bridges.

Such was the traffic growth immediately following this period that both of the Canning Bridges were widened by an extra lane each in 1965.

The bridge had a reinforced concrete overlay constructed in 1984 to prolong the life of the decking and timber superstructure.

Heritage Importance

The pair of bridges that is Canning Bridge was recognised in 2006 by inclusion onto the Heritage Council of Western Australia Register of Heritage Places. This recognises both the history of the site and the representative nature of the current bridge construction.

Prepared by Lloyd Margetts, Senior Bridge Engineer, Main Roads WA

Canning Bridge just after construction, 1937. This approach was modified to accommodate the construction of the Kwinana Freeway in 1958/59.

Mt Henry Bridge

Beam units being placed on falsework truss supported on piers and by tower

History of the Mt. Henry Bridge

The north-south freeway system, which provides for the bypassing of the Perth central business district, was planned and developed by Professor G. Stephenson and Mr. J. A. Hepburn in 1955. Apart from the completion in 1959 of The Narrows Bridge, which connects the north and south banks of the Swan River, the whole Freeway plan was adopted by the WA State Parliament in 1963. There have been amendments made to the plan on a number of occasions, brought about by changing demands and following further studies.

The first stage of the southern extension of the road, designated The Kwinana Freeway, saw the completion of the Canning Interchange in 1979. The second stage saw the extension reach South Street, when it was officially opened on 9 May 1982. This included the construction of the Mt. Henry Bridge across the Canning River and its completion, following 34 months of work, in April 1982.

Bridge Statistics

When completed, the bridge was (and still is) the longest road bridge in Western Australia, being 688 metres in overall length (including abutments) and 28.8 metres in width. It accommodated 6 lanes of traffic with a central concrete median barrier. It consists of nine continuous spans of precast, double-cell, single box, post-tensioned, concrete segments, supported by sculptured reinforced concrete piers. There are 7 spans of 76.25 metres and 2 end spans of 63 metres. The depth of superstructure is 3.6 metres. For aesthetic reasons, the soffit is parabolic. The deck has a 3 degree cross fall, each side of the centreline. An unusual feature of the bridge was the provision of a 3.15 metre pedestrian walkway and cycleway cantilevered from the bottom flange of the superstructure, on each side.

The bridge piers are made continuous with partly submerged pile caps, supported by composite piles which comprise a precast pre-tensioned concrete upper section and a steel universal column lower section. The average length of pile was 42 metres, being driven through river mud and sand into hard siltstone.

The abutments are reinforced concrete cellular structures. The fixed abutment on the Mt. Pleasant side is founded on universal column sections, while the Mt. Henry side, at the bridge expansion joint, is founded on a raft footing.

The bridge services include two 914mm diameter sewerage pressure mains, a 325mm diameter high pressure gas main, Telecom mains, SEC mains, drainage, water and electrical facilities for the bridge itself.

Quantities

Total quantities in the bridge consist of the following;

Piling, Mt. Pleasant abutment, 43 no.	1,870 m
Piling, composite to piers, 184 no.	7,530 m
Precast deck units	258 no
Concrete, precast units	10,470 m3
Concrete, in-situ	6,530 m3
Reinforcing steel	3,068 te
Stressing wire, 7mm diameter	754 te
Stressing strand, 15.2 mm and bar, 38mm diameter	140 te

Design and Construction

The bridge was designed by the Main Roads Department of Western Australia and constructed by the Clough Engineering Group. Influenced by the high cost of constructing the Stirling Bridge (1972-1974) temporary mid-span falsework support

piers, and backed by detailed calculations from Swiss consulting engineers Cepas Plan Ltd. of Zurich, Clough developed a cable stayed tower which partially supported the bridge falsework from above and acted as a crane to lower the bridge precast deck units onto the falsework truss. (The whole Falsework System received the Engineering Excellence Award for 1981 from the Western Australia Division of the Institution of Engineers Australia.)

River piling, pile caps and piers were all constructed using crane mounted barges, a self-propelled "Schottel" barge and a "Combi" barge, made up of 20 standard interconnected modules, and together sufficient to carry all superimposed loading. A temporary jetty was built on the Mt. Pleasant side of the river to provide for the loadout of all materials and equipment.

Piling

The Mt. Pleasant abutment piles, 43 No. 310 UC 240 steel, were driven with a Kobe K35 diesel hammer mounted on a 30RB crawler crane. The piles were up to 43m in length and raking 3:1 and 4: 1. The top 9m of each pile was painted with two coats of tar epoxy enamel.

Each of the 8 river piers is supported by 23 composite piles, comprising a 310 UC 240 steel lower section and a 550mm square precast, prestressed concrete upper section, driven to an ultimate capacity of 6000 kilo-Newtons. The piles in each pier were arranged with a central vertical pile and the other piles "fanning out" in all directions at rakes varying from 1 in 20 to 1 in 5. Composite piles ranged in overall length from 38 to 47 metres, with the concrete portion from 13.5 to 21 .5m. Penetration of the lower section into the Siltstone varied from 12 t015m. The heaviest pile handled weighed 24 te. Each of the concrete upper pile sections contained 16 No. x 12.5mm dia. pre- tensioned stressing strands and pulled to 128kN, prior to casting. Each section was cast about an embedded 3m x 310 UC 240 pile stub.

The river pier composite piles were driven by a Kobe KB60 diesel pile hammer, mounted on 30m leaders attached to a 61RB crawler crane. This combination was assembled on the Combi barge and manoeuvred by means of anchors and barge mounted winches. Pile sections were delivered by the Schottel barge.

Pile Caps

The elliptical pile caps are 10.5 x 4.0 x 2.0m depth, containing 68 m3 of 30/20/200 mPa concrete, which was super-plasticised with Melment L10 (1045mls per 100kg cement) to achieve a high slump. This was necessary to ensure placement and compaction around the congested reinforcing steel. Each pile cap contained 15 tonnes of reinforcing steel, comprising up to 13 mats of interwoven layers, together with extra pier and temporary pedestal starter bars. All-up, the reinforcement amounted to approximately 315kg/m3 of concrete.

Piers

The 8 sculptured and bifurcated piers, which varied in height to suit the bridge profile, contained an average of 60m3 of 45mPa super-plasticised concrete in a total of 475m3. A retarder, Plastet NO.2 (up to 500ml per 100kg cement), was added to the mix to increase the effective time in which to be able to place the concrete. These additives were phased out as the pour height increased in each pier. Cold worked and close tolerance bent reinforcement averaged 406kg/m3 of concrete for each pier, in a total of 193te. The surface of all piers was sandblasted, following the deck construction.

Precast Deck Units

The tender documents required the contractor to provide an on-site batching plant that was capable of providing tight quality control of the 45mPa design strength concrete used in the manufacture of the 242 x 110te hollow deck units and the 16 x 115te solid diaphragm units. The batching plant chosen was a fully automatic 1m^3 Marte 1040, c/w 120te capacity air-blown cement silos. Two transit mixers provided sufficient transport of concrete to the casting yard and its placement using a mobile conveyor.

Two sets of railed telescopic steel shutters, 24.4 x 3.6 x 2.55m long, were sufficient to allow for a continuous cycle of cleaning, placing prefabricated steel reinforcement cages c/w all cable ducting, casting, steam curing, lifting and storing. The whole casting and storing of the units was straddled by a 150te SWL portal gantry crane. Steam boilers, 3 no. x 30HP automatic, with chart recorders, and a steam tent, allowed the units to reach their target strength, 30mPa for lifting, within 24 hours. Units were stacked two high and at 90deg. to their final alignment.

Falsework Truss and Tower

The falsework truss (81.6 x 15 x 14.6m) comprised three main trusses spaced 7.5m and spliced together in 20te sections using M30 friction grip bolts; all up weight of the truss was 540te. A removable 20m section was assembled around each pier in turn. The falsework tower (40 x 7.5 x 2.5m) comprised two strutted columns made up of a lattice of braced 31OUC sections on a square grid of 1.5m; all up weight of the tower was 165te. Tower raising and lowering was achieved by using 2 x 500te jacks (fixed to the completed deck) and segmented tie cables. Backstay cable tensioning was carried out at the top of the tower using 2 x 250te jacks pulling 4 cables (42 x 7mm). The cable stayed concept allowed the rear end of the falsework support truss to be suspended from the 17m cantilever of the previous stage of deck construction. The mid span of the truss was supported by cables fixed to the head of the tower and the forward end of the truss was supported by 1000te capacity guided sliding bearings seated on temporary pedestals on the leading pile cap. This configuration finally allowed 50% of the total dead weight of 4000te of each stage to be carried through the pile cap, 17% to be hung off the free cantilever and the remaining 33% to be suspended from the truss/tower front stay cables. As the dead weight deflection of the truss tended to increase as more units were placed, the head of the tower was pulled back by four backstay cables.

Deck Unit Placing

Precast units were lifted from storage by the gantry and placed on a rail mounted hydraulic powered unit transporter. The unit

was supported on rubber bearings at each web. Upon reaching the tower, a second lifting beam was lowered and attached to the top of the unit using BBR cables. The unit was raised off the unit transporter, by means of a twin 10te line-pull winch, and allowed to swing out over the edge of the deck. It was then rotated 90deg. by hand and lowered down onto the falsework trolley. It was again seated on rubber bridge bearings which acted as shock absorbers during transport. The unit was transported along the top of the truss to its final position before being jacked down onto preset packers. Packing heights allowed for the gap between bridge soffit and the truss, the truss deflection under dead loads and the preset for bridge post tensioning. Great care was need when positioning the pair of solid diaphragm units, relative to the top plate of the permanent bearings (2500te capacity), to allow for temperature movements of previous spans and the truss itself. The main post-tensioning cables were reeved through the diaphragms and hollow deck units before pouring the 450mm in-situ joint and the 1OOmmjoint (target strength 52mPa) between the deck units.

Post Tensioning

The permanent prestress cables having been pulled through the unit ducting and made continuous with the previous stage, a strict post- tensioning sequence took place, interspaced with de-stressing of the backstay cables. This is a very simplified summary of a much more ordered sequence of work to complete each stage of construction. An 800te prestress jack was used to tension the larger cables. Each of Stages 2 to 8 comprised 27 main longitudinal cables (9 per web of 125 x 7mm x 5110kN), 12 transverse diaphragm cables, 12 bottom slab cables, 18 vertical and 40 longitudinal Macalloy bars in the diaphragm. Following MRD approval of the final prestress, all cables were grouted with a water/cement ratio not more than 0.50.

Truss and Tower Handling

The use of preloaded collapsible sand jacks around each pier, as part of the packer height, enabled a positive and quick separation and release of the falsework truss away from the bridge soffit, after prestressing for a particular deck stage was completed. Handling of the falsework truss commenced, by positioning the Schottel barge underneath the 11ate cantilever section, unbolting the splice joints around the pier and transporting the truss to a parking position adjacent to the temporary jetty. The Combi and Schottel barges were then positioned underneath each end of the 430te main section, which was then lowered onto the barges using 8 x 60te hydraulic extended-ram jacks. Following the movement and connection to the next span, the Schottel barge returned to pick up the parked cantilever section and manoeuvre it into place, to be reconnected to the main truss section around the next pier.

The Tower was initially lowered onto a beam supported by an 'A' frame mounted on two pairs of Unit Transporter bogies travelling on the completed deck. With the tower hinge disconnected from the deck, a powered transporter moved the tower along the deck until the head engaged with a second powered 'A' frame travelling on top of the truss. In its new location, the base was fixed to the deck, the tower raised and the backstay cables reconnected.

Placing the last beam

Services

Services to the bridge comprised electrical, water, drainage, public sewerage and an external gas main. The electrical work was particularly significant, in the amount of power and lighting fixtures that were required (some 660 switchboards, lights and switches). Cable lengths up to 475mm were pulled through the structure using a combination of rollers and snatch blocks and co-ordinated with the use of two way radio. All up there were some 28.5 kilometres of electrical cable installed.

The single finger-plate expansion joint at Mt. Henry abutment allows for +/- 199 mm of expansion. The rotation joint at Mt. Pleasant abutment was a single 30.7 metre Wabo heavy duty compression seal.

Guard and hand railing to a combined length of 2,870 metres was installed on the bridge deck and on the cantilevered footways.

Tender and Final Payment

The Tender price at award, on 14 March 1979, was $10,133,000. The Final Payment at Completion, after allowing for some variations and significant escalation, was $13,971,000.

Construction on site commenced on 31 May 1979 and contractual completion was 24 April 1982. Not a single hour of work was lost through industrial unrest caused by site working conditions or disagreements.The Safety record was very good, with no major incidents recorded, and the percentage of hours lost was 1.07% from some 380,000 hours worked.

Prepared by Tony Quinlan

Stirling Bridge

Stirling Bridge Aerial View

History of Stirling Bridge

A bridge over the river at Fremantle has always been a key focus of interest since the colony was settled in 1829. When completed Stirling Bridge was the latest construction to span these waters and to cope with increasing traffic loads in the area.

Stirling Bridge forms a link between Stirling Highway and Cockburn Road as part o f the bypass to the City of Fremantle. It was designed to meet the traffic requirements generated by the continuing development of heavy industry in the Kwinana area a general urban expansion. The bridge has been planned in two stages. The first completed in 1974 and the second, to be built when required will duplicate the existing structure on the upstream side, adding another three lanes and giving a combined width of 35m.

Bridge Statistics

The Stirling Bridge is a continuous seven span twin post-tensioned segmental spine beam concrete bridge. The overall length is 415m. The individual spans are from the south 23.8m, 81.4m, 75.3m, 69.2m, 63.1m, 54.9m, and 47.2m respectively.
The bridge is fixed on the south abutment and the movement taken in finger joints on the north abutment. The superstructure is supported on steel roller bearings.
The bridge deck is 16.4m wide comprised of a 14.6 m four lane roadway and a 1.8m wide footpath on the downstream side.
The clearance in the navigation channel is 9m and over the roadway 6m. The bridge profile rises gently from the south abutment to a third of the way across then falls gradually to the north abutment. It has a cross fall grade of 1:40.
The balustrade and guard rails are galvanized steel coated with high quality paint due to the corrosive environment.
A 450 mm diameter water main is slung under the roadway between the boxes and provision was made for power and communication ducts through the inside of the boxes and under the footpath slab.

Quantities

Pier piles: 74 Nos.,2533m, 0.73m dia. by 13mm mild steel.
Abutment piles: 21 Nos.,1035m, 0.47m dia. by 9mm mild steel.
Reinforcing steel: 1,110 tonnes.
Concrete: 7,925 c.m.
Prestressing steel: 285 tonnes.
Precast segments: 292.

Design and Construction

Design plans and specifications were prepared by Maunsell and Partners on behalf of the Client, the Main Roads Department of Western Australia.

Tenders were called and the lowest tender at $ 2,560,000 was submitted by J.O.Clough & Son Pty Ltd. This was accepted on 19 June 1972 requiring a contract completion by 14 July 1974.

The contractor proposed to precast all the concrete superstructure segments at its Kewdale Precasting Yard and transport these to site on low loaders. They proposed to build temporary mid span piers and to use these and the permanent piers to support half span falsework trusses on which to erect the superstructure. Floating equipment would be used to construct the piers in the river. Purpose built lifting and moving equipment was specially designed to fit the purpose.
The pier piles were top driven with a K35 diesel pile hammer using a flying leader. Piles were founded on a layer of dense silt known as the Swan River Silt which was about 40m below the water surface. A test pile was driven in Pier 2 and tested to

Units being placed for downstream row stage 2


Placing a beam unit

380 tonnes and the permanent piles were then driven to a set in excess of that to which the test pile was driven. A pile test was also carried out on a north abutment pile to ensure the required capacity was reached.

To support the individual segments and the false work trusses sand jacks were used to enable them to be released under load after stressing was completed. Once positioned and aligned on the falsework the prestressing cables were threaded through the ducts and the 75mm joints between the segments filled with a specially designed concrete mix.

The BBR post-tensioning system was used. The main web cables were encased in ducts in the webs of the segments and comprised 81 Nos., 7mm dia. wires. There were six in each web and these were subsequently stressed to approximately 400 tonnes. Four 56Nos., 7mm dia. wire cables were placed in the bottom flanges of the spans and these were stressed to 275 tonnes. Cable ducts were grouted after stressing.

The bridge was constructed from the south end in ten stages; 1a,1b,2a,2b etc. as the two box girders advanced across the river. The respective stages for each box girder were joined at the quarter points of the spans. This was a rather delicate operation which required locking the built stage to the one supported on false work while the last joint was poured and the stressing begun. As the strength of the concrete increased so did the tensioning of the primary cables until a contiguous structure had been achieved.

The top edges of the boxes were clad with a small finishing panel to neatly define the line of the superstructure. These were cast with an 'off white' concrete and had a bush hammered finish.

The roadway was sealed with a sprayed fibre glass reinforced bituminous coating then paved with two layers of asphalt.

The bridge was completed three months ahead of schedule and opened to traffic by the Premier of Western Australia Hon. Sir Charles Court, O.B.E., M.L.A. on 17 May 1974.

The bridge gracefully sits in its environment displaying the elegant lines of its thoughtful design. The reduction in depth of the bridge beams from a maximum of 3.4 metres at the south abutment to a minimum of 1.8 metres at the north abutment complements the reduction in span lengths and soffit clearance height from south to north and produces a pleasing appearance, particularly when viewed in elevation. At the time of its construction it was the longest bridge in Western Australia.

Prepared by Peter Knight


Stirling Bridge Elevation of Completed Structure

Fremantle Bridges

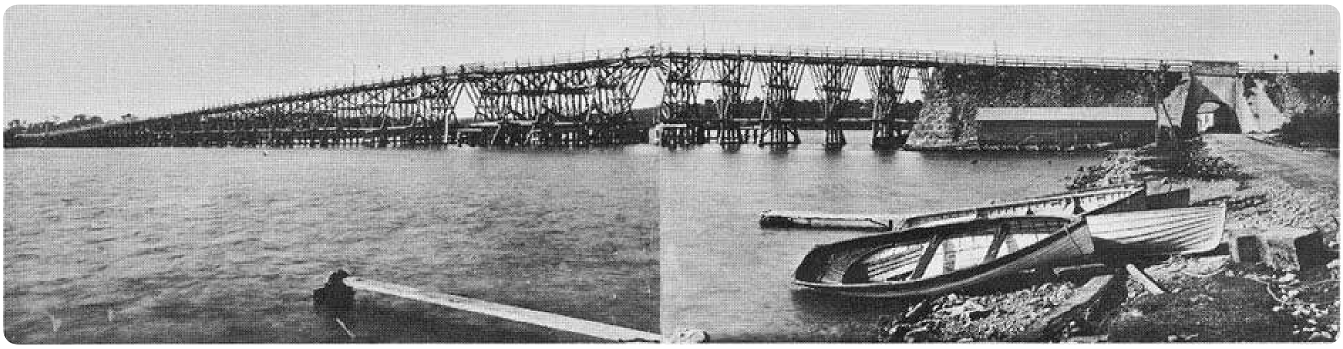


Fig.1 North Fremantle Bridge.

Fig 2 North Fremantle Bridge circa 1890

History of Bridge Site

The present Fremantle Traffic Bridge is 70 years old, having been opened in 1939, but it is the fourth bridge to be built on this site. The first bridge was built in 1866 and the three earlier bridges are of particular interest as they illustrate the great changes which have transformed Fremantle over the last 180 years.

When Governor Stirling established the Swan River settlement in June 1829 he founded two initial townships, a port settlement on the southern side of the Swan River, which he named Fremantle, and an administrative capital on the north bank of the river below Mount Eliza, which he named Perth.

By siting Fremantle and Perth on opposite banks of the Swan River Governor Stirling created an immediate need for bridges across the river to connect the two townsites. The first bridge was built at the Perth Causeway in 1843 but the necessary technical resources and money required to build the much larger structure required to cross the Swan River at Fremantle did not become available until 20 years later.

North Fremantle Bridge

After 1850, when Western Australia became a penal colony, a programme of bridge construction was undertaken by convicts under the supervision of a Company of Royal Engineers and construction of the high level North Fremantle Bridge was finally authorised by Governor Hampton in 1863. This was by far the largest and most difficult bridge to be built by the Royal Engineers with convict labour and Fig.1 is an early photograph of the completed structure, which was located immediately upstream of the present Fremantle Traffic Bridge. It comprised a very long and high timber bridge, a massive embankment at the southern end of the bridge and a small arch bridge, which you can see on the right of the photograph, to provide access under the embankment.

Work on the bridge commenced in May 1863 and the bridge

was opened to traffic in November 1866 but was not finally completed until October 1867, a period of four and a half years. The man responsible for the design and construction of this bridge was James Manning, a Clerk of Works attached to the Imperial Establishment who had accompanied Captain Henderson R.E. out to Western Australia in the 'Scindian' in 1850. He had previously trained in England as a civil engineer and, as Clerk of Works, was responsible for the construction and maintenance of jetties and bridges throughout the colony.

The bridge had a total length of 940 feet (286m) and consisted of two 45 feet (14m) navigation spans and 33 standard spans of approximately 26 feet (8m). The width of the bridge deck was 18 feet (5.5m). The most remarkable feature of the structure was its great height to allow barges to sail under the bridge. The navigation clearance under the two navigation spans was 44 feet (14m) – equivalent to a five storey building. An enormous amount of timber was used in this bridge. In addition to the 342 round timber driven piles, some up to 55 feet (17m) in length, there were over 78,000 feet (23,800m) of sawn timber, all of it sawn by hand.

In the early 1890's this high level bridge was reported to sway in high winds and to be unsafe. In 1896 a number of inspection reports, which had been made on the bridge between 1891 and 1896, were tabled in Parliament and resulted in the maximum allowable load on the bridge being reduced to 1¼ tonnes. The following notice then appeared in the Government Gazette:

"On and after the 27th October 1896 and until further notice, no persons shall be permitted to drive or lead any mob of cattle , camels or horses exceeding four in number over along or across this bridge or any part thereof..."

Low Level Bridge

By 1896 commercial activity in Fremantle had increased significantly as a result of recent gold discoveries in the State and the Government decided to build a wider, stronger bridge on the downstream side of the existing bridge, but at a much lower level, and this became known as the Low Level Bridge. This retained the 45 feet (14m) wide navigation channels but the vertical clearance under the bridge was obviously much less. This was now acceptable because the Fremantle to Guildford Railway had by then been constructed and replaced the old river sailing barges for the transport of goods up the Swan River.

The Low Level Bridge was opened on the 28th September

Fig 3 Low Level Bridge circa 1900.

1898 but the old North Fremantle Bridge was retained for use by pedestrians. It was intended that the Low Level Bridge would only be a temporary structure while the old bridge was removed and replaced with a wider structure having two 75 feet (23m) navigation openings. Nothing further was done however until ten years later, in 1908, when the Fremantle and North Fremantle Municipal Councils wished to extend the Fremantle tramway system to North Fremantle.

The temporary low level bridge was at the wrong level for a tramway and the approach roads were also unsuitable. A careful inspection of the old North Fremantle Bridge was therefore made and it was found that out of 319 piles examined 306 were absolutely sound and the others only had minor defects. In view of their excellent state it was decided to use them as a foundation for a new bridge deck.

Renovated High Level Bridge

The old deck was removed and the piles cut down to an appropriate level while additional piles were driven to provide for a wider bridge which could carry both road traffic and trams. The Renovated High Level Bridge was opened on the 18th June 1909, after which the Low Level Bridge was closed and later demolished.

Fig 4: Renovated High Level Bridge

Fig. 4 shows the Renovated Bridge with the new tramway, and the adjacent Low Level Bridge being demolished. The bridge was 39 feet (12m) wide and included a 23 feet (7m) wide carriageway for two lanes of traffic, a 12 feet (3.7m) wide tramway and a 4 feet (1.2m) wide footpath. The renovations were so extensive that it was virtually a new bridge, which therefore ranks as the third bridge to be built on this site.

In 1926 the Government created a Department of Main Roads to be responsible for construction of all main roads and associated bridges, including the Renovated High Level Bridge. By the 1930's the condition of the timber piles in this bridge had deteriorated due to attack by teredo marine borers and the deck timbers required constant maintenance. It was therefore decided in 1937 to build a new bridge immediately downstream of the existing bridge which became known as the Fremantle Traffic Bridge.

Figure 5: Fremantle Traffic Bridge

Fremantle Traffic Bridge

A concrete bridge was initially considered for this site at an estimated cost of £650,000 but, as there were plans to extend the existing harbour further upstream in the future, it was decided to construct a much cheaper temporary timber bridge at an estimated cost of £75,000. In view of the planned harbour extensions the bridge was only expected to be in use for 3 to 5 years but has now been in service for 70 years. Fig.5 is a photograph taken in the 1940's, looking towards North Fremantle, and shows the old Renovated High Level Bridge just upstream, which was not demolished until later in 1947.

The bridge is 720 feet (219m) long with two navigation spans, each having a clear navigation clearance of 51 feet (15.5m) between fender timbers, a 40 feet (12m) wide underpass at the south abutment and 22 timber spans of 20 feet (6m). The two navigation spans, the intervening length between them and the underpass are spanned by a steel superstructure consisting of longitudinal girders, cross beams and stringers, supporting a timber deck.

The abutments are constructed from mass concrete founded on timber piles at the north end and on limestone at the south end. The piers consist of Jarrah timber piles and the transverse cap beams spanning between the timber piles were originally Karri timber but have subsequently been replaced with steel channels. Apart from the steel navigation spans and underpass, all the main longitudinal beams spanning between the piers (known as stringers) are round Wandoo logs. Transverse Jarrah bearers, which sit on top of the timber stringers, support longitudinal Jarrah deck planks.

The design and construction of the bridge was directed by E.W. Godfrey, bridge engineer for the Main Roads Department from 1928 to 1957, who was responsible for the construction of many outstanding bridges throughout Western Australia. For the Fremantle Traffic Bridge he devised an ingenious method to protect the timber piles from attack by teredo and other marine borers. It consisted of an external sleeve of concrete pipes, which were lowered over the head of each pile after they had been driven, and extended from 4 feet below the river bed to 4 feet above normal water level. The annulus or space between the pile and the inside of the pipe was then filled with clean sand. This proved successful in protecting the piles for many years.

The Fremantle Traffic Bridge was opened on the 15th December 1939 by the then Premier, J.C. Willcock. In his address the Premier mentioned that the opening coincided with the completion of the Stirling Highway after 6 years of construction and a change in public transport from trams to buses on this particular route. The Premier also remarked that the Commissioner of Main Roads, Mr E. Tindale, had assured him that the bridge could also do service for the next 40 years if required and this promise has certainly been honoured.

In 1978 the bridge deck was strengthened with a concrete overlay and major repairs to the bridge, costing over $1 million, were carried out in 1992. These included strengthening the top sections of the piles, which had been weakened by rot at the water line, and replacing the earlier protection against marine teredo attack by encasing the piles in concrete down to river bed level. The original Karri halfcaps have also been replaced with steel angles. Figure 6 is a recent photograph of the bridge showing these various repairs. Also of interest are the old pile stumps in the foreground. These are the remains of the original timber piles in the 1866 North Fremantle Bridge.

Prepared by Peter Palmer

Figure 6: Fremantle Traffic Bridge in 2009

Appendix

Narrows Bridge Duplication (2001)

By 1998 the original Narrows Bridge was carrying 155,000 vehicles per day and the State Government announced plans to widen it. The initial solution was to build a smaller bridge immediately west of the existing structure and to join the decks of the two bridges to form a contiguous roadway. However this plan was superseded by a decision to build a new bridge separated from the original bridge by a gap of six metres. Main Roads WA called tenders for the design and construction of the new bridge in July 1998, with the proviso that the new bridge had to have the same profile and look the same as the original.

Leighton Contractors, in association with designers Connell Wagner, was, in March 1999, awarded a $49 million contract to design and construct the bridge. Their proposal was to use the incremental launching technique, whereby 28 metre concrete bridge beam segments were cast in a bed on the south abutment, post tensioned to the previous completed segment, and pushed by hydraulic jacks 28 metres northwards over permanent and temporary piers until the front end of the twelve stages reached the north abutment. The original Narrows bridge has eight rows of I beams connected by diaphragms at the piers and intermediate points. The new bridge has four rows of larger I beams, the east and west pairs connected with diaphragms before launching separately. Incremental launching is best suited to bridge beams of constant depth, and because of the specified curved soffit of the Narrows bridge beams, during launching the pairs of beams had to be supported on elevated temporary supports, these being removed when the beams were lowered onto permanent piers after the launching was completed. Then an insitu slab was cast along the bridge centre line joining the east and west pairs of beams.

The bridge was opened to traffic on 26 February , 2001.

Figure 1: Elevated temporary supports at piers

Figure 2: Launching noses of east and west beams

Figure 3: Soffit between east and west beam pairs

Figure 4: Aerial view of launching

Narrows Railway Bridge 2005

During the construction of the second Narrows road bridge a decision was made to build a suburban railway, along the freeway alignment, from Perth to Mandurah and Rockingham. Leighton Contractors won the contract to build the railway crossing at the Narrows site and engaged the design consortium of GHD, Coffey Geosciences and Wyche Consulting to assist. The rail track was supported on nine steel box girders, each 54 metres long and weighing 99.5 tonnes, made in Kwinana by Structural Marine Engineering, and lifted into place by mobile crane. The girders were supported on concrete piers in the six metre gap between the 1959 and 2001 bridges.

The bridge was completed in 2005 and the first trains passed over the Narrows site in December 2007.

Figure 5: Soffit of steel railway bridge girders

Mt Henry Bridge Widening and Strengthening (2004 – 2006)

To accommodate the suburban railway line to Mandurah the bridge was widened and strengthened between 2004 and 2006. The tender documents called for a symmetrical widening of the existing bridge. However the successful tenderer, Leighton Contractors, with their design consultants, Wyche Consultants, GHD and Coffey Geosciences, proposed a completely independent bridge on the western side and fitting into the existing bridge. The north bound roadway would be carried by the new bridge and the south bound roadway carried by the existing bridge. The railway formation was to be supported by the strengthening of the existing bridge.

Due to restrictions on land availability the new bridge had to fit into the existing one with the new deck overhanging the old one. The new bridge east top cantilever clears the old kerb by a minimum of 85 mm and the vertical gap between the lower cantilevers of the two bridges is approximately 185 mm.

Incremental launching

Leighton Contractors used the incremental launching method for putting the bridge superstructure in place. Due to the 76 metre spans temporary mid span piers had to be used to support the launching nose (which was one used at the Narrows site in 1999 – 2001, albeit with some modifications) and the forward end of the concrete beam. The use of temporary piers also gave the construction team tighter control over displacements during launching which was critical in ensuring the new bridge did not contact the old bridge during the construction phase. The design and construction of the temporary piers provided a major challenge for the design and construction team. Tubular steel piles, similar to those used for the permanent piers, were used. The designers were concerned that the upper soft alluvium layer of the river bed would provide little lateral restraint to the piles.

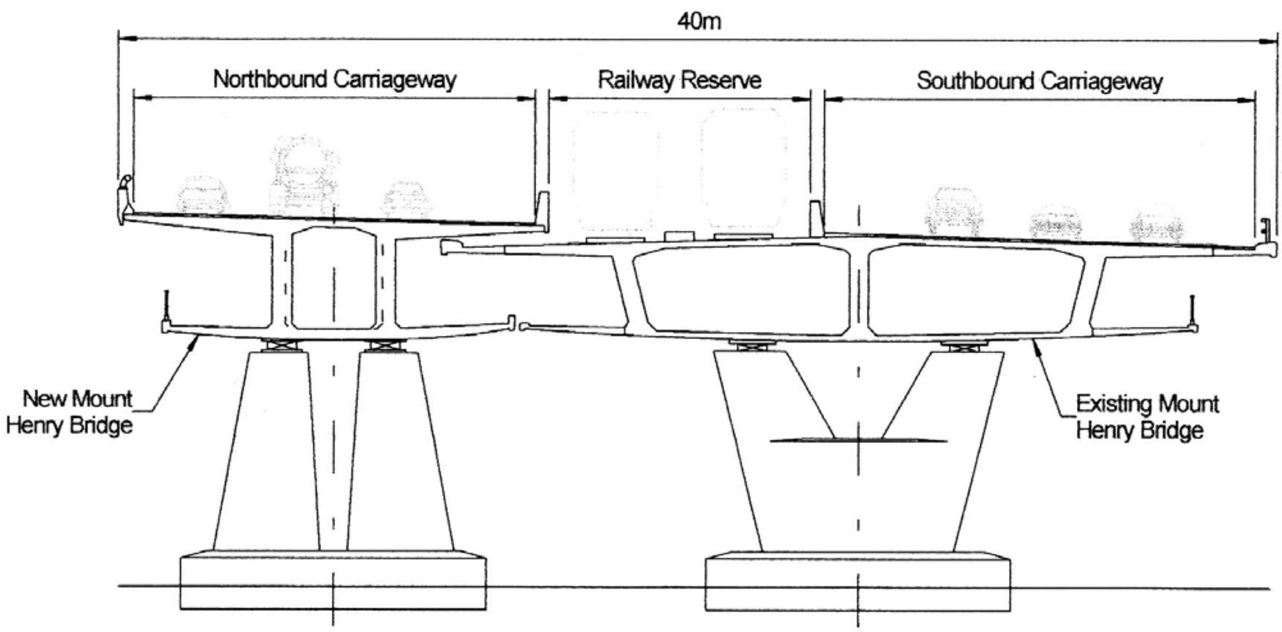


Figure 6: Cross section through original and duplicated Mt Henry Bridges

A solution was developed whereby the temporary pier pile caps were connected to the existing bridge in the transverse direction by a flexible prop system capable of accommodating longitudinal movements. Longitudinal connection was achieved by running prestressing cables between the temporary and permanent piers such that each temporary pier was tied to adjacent permanent piers. This bracing system permitted each temporary pier to be supported by only four piles. Extensive monitoring of the movements of each temporary pier during stressing of the bracing cables enabled revisions of the stressing sequence to achieve an optimum result. Results confirmed that the geotechnical engineer's estimate of the lateral soil stiffness values were conservative.

Figure 7: View under bridge showing bracing of temporary pier

Deck construction and prestress

Leighton Contractors opted to launch the superstructure in 25.4 metre lengths, approximately one third of the main span lengths. To speed up construction they established a two segment casting bed, whereby in the rear bed the bottom flange and webs were monolithically cast, and simultaneously in the front bed the top flanges were cast. In addition launching prestress operations were minimised by running each concentric prestress cable for three segment lengths (equal to one main span length of 76 metres). Hence for the construction of each segment only one third of the concentric prestress had to be applied.

The efficient design of the temporary piers, the two part construction staging of the deck, and the concentric prestress arrangement all contributed to the speedy construction of the duplicate Mt Henry Bridge, which was opened to traffic two years after the design and construct contract was let.

Figure 9: Launching of Mt Henry Bridge in progress

Figure 8: Casting bed for superstructure beam segments

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